NEW MEXICO TECH LEAD-FREE SOLDER RESEARCH

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ABSTRACT

In recent years a growing concern for lead-free solder has propelled industry to re-evaluate surface mount technology (SMT) production. This is based on the European Union's reduction of hazardous substances (RoHS) directive for a cleaner environment. Military and Aerospace industries, though they have been given exemption from this directive, are very dependent upon commercial industry that must be RoHS compliant. Therefore RoHS issues are important to Military and Aerospace industries. Commercial industries are not required to meet the rugged environmental standards required for military and aerospace applications. It is necessary for further research to be conducted on commercial lead-free solders (using military standards) that will be used for military applications. The varying properties of lead-free solders as compared to the Tin Lead (SnPb) model have made it so that traditional methods of processing can no longer be utilized, thus raising Diminishing Manufacturing Sources and Material Shortages (DMSMS) concerns within the military and aerospace communities. Lead-free solder properties vary with the percentage of alloy composition, heat treatments and crystallography. Further research is needed in characterizing and creating valid models for lead-free solder joint reliability. The Microelectronics Testing and Technology Obsolescence Program (METTOP) is a small microelectronics testing and research facility located at New Mexico Tech, in Socorro, NM. Our facility has recently started a lead-free solder research program, to assist in mitigating DMSMS issues and concerns regarding reliability-information, or the lack there of, on lead-free solders for use in Military and Aerospace applications. Our initiative is to conduct smaller research projects making contributions to the greater body of knowledge by filling in gaps of current research. Our initial efforts are focused on performing vibration reliability testing of lead-free alloys. This paper documents the most recent results of the research done at New Mexico Tech.

Key words: lead-free, solder, vibration

INTRODUCTION

METTOP is an electronics testing facility associated with New Mexico Tech in Socorro, NM. METTOP's mission is to help meet the DMSMS issues by testing, evaluating and assessing the wide range of microelectronic components and materials that comprise many of today's sophisticated military, space and commercial systems. Consistent with this mission, in early 2007 METTOP began an effort studying the reliabilities of lead-free solders. This effort was motivated by the recent RoHS directive in the European Union, banning the use of lead in electronics. While this directive does include an exemption for military/aerospace industries, these industries are still being forced to go lead-free due to supply chain issues.

After learning about what has already been done in the area of lead-free research, it was decided that METTOP could best contribute by focusing on smaller research projects to fill in the body of knowledge. In mid 2007, METTOP joined with Naval Surface Warfare Center (NSWC) Crane and Purdue University on their Project 1722-Impact of Lead-Free Components on Military Repair. The purpose of this project is to develop with NAVSEA Crane a technical team of industry, academia and military to evaluate existing data and recommend strategy for DOD on military electronics affected by the lead-free initiative. Emphasis is placed in four areas: tin whiskers, solder joint reliability, copper dissolution and cross-contamination. METTOP has focused on the issue of solder joint reliability, particularly in the area of vibration testing.

METTOP has also recently begun getting involved with the Lead-free Electronics in Aerospace Project Working Group (LEAP-WG). This working group was formed in 2004 and includes members from all stakeholders, including all branches of the military, aerospace, market segments, supply chain and geographic regions. The group addresses issues that are unique to aerospace and military and within the control of aerospace and military. The purpose is to develop and implement actionable deliverable items that enable the aerospace industry to accommodate the global transition to lead-free electronics. The deliverable items address problems that are unique to, and are within the control of the aerospace industry.

The first research project that METTOP conducted served as a follow up to the Joint Council on Aging Aircraft/Joint Group on Pollution Prevention (JCAA/JGPP) lead-free study. The JCAA/JGPP study is the most comprehensive study of lead-free solder joint reliability from a military/aerospace standpoint to date. In this study, printed circuit boards (PCB boards) using several different lead-free solder alloys were subjected to a variety of conditions, such as vibration, shock and salt fog atmosphere. For this new study, it was desired to follow up on the vibration study conducted by Boeing in the original project [1]. By doing a similar study, this will contribute more information to the greater body of knowledge. The follow up study was accomplished by re-using the PCB boards from the JCAA/JGPP salt fog study. The intent was to modify the PCB boards by applying stiffeners, to see how the stiffeners affected reliability. More accelerometers were added in order to get a more detailed data set, and allow us to do more complex analysis. While there are interesting structural implications to these tests, this discussion is limited to only the electrical continuity results that were obtained.

METHODOLOGY

The objective of this study was to determine the effects of vibration environments on already stressed (salt atmosphere) PCB boards, reinforced with stiffeners, from the JCAA/JGPP study [2]. Nine PCB boards consisting of SnPb, SAC, and SACBi solder were used in this study. A commercially available software program (CirVibe) was used to do a simulated modal analysis of the boards. The modal analysis helped to determine the regions of maximum stress, thus assisting in the placement of accelerometers and the stiffeners. Event detectors monitored and recorded intermittence in the solder joints during the vibration test. The data acquired from this study will aid in the ongoing commitment to lead-free research by the JCAA/JGPP consortium.

All nine PCB boards were provided by NSWC Crane, and were the actual boards from the JCAA/JGPP salt-fog study. The PCB boards were tested for continuity using a multi-meter. All components were tested as well as their traces for any high resistance values. All data was recorded and used as a base line to establish preliminary failures before vibration testing. Nineteen parts failed before any vibration testing took place. Three components had broken even before the salt fog study took place. The remaining sixteen components most likely failed as a result of the salt fog corrosion on the boards. None of these components were considered in the final analysis of the data. Seventeen of the components were Thin Quad Flat Pack 208s (TQFP-208s), one was a Ball Grid Array 225 (BGA-225) and one was a Plastic Dual Inline Package 20 (PDIP-20), seen in Table 1.

Test Fixture/Apparatus

Twenty foot twenty-four gauge stranded wire was soldered on to the through-hole pattern of each board. Each wire was then soldered to a designated pin for attachment to the event detector. Each board contains fifty-five components, with twenty-six leads on the left side and twenty nine leads on the right side, two ground wires for each set. Wires were attached to the boards and glued down using epoxy to prevent flexing or breaking during the vibration test. Groups of twenty-six and twenty-nine wires were then bundled and covered using 1” tinned cooper braided shielding to cut down on electromagnetic interference. The nine boards were then mounted in the test fixture with a spacing of 1”. Wedge clamps were used to secure the boards into the test fixture. The test box fixture was machined using 20-24 Aluminum.

Table 1. Components Failed from beginning. Highlighted values indicate bad components, the rest are failed due to salt fog corrosion.

Board #	Component failed:	Type of component:	Resistance Value from voltmeter Ω
104	U56	BGA-225	Open circuit with in component from salt fog study
104	U3	TQFP-208	.54k unstable
104	U57	TQFP-208	40 unstable
104	U48	TQFP-208	.25k unstable
104	U35	PDIP-20	Open circuit with daisy chain from salt fog study
104	U34	TQFP-208	Failed
105	U3	TQFP-208	.23k unstable improperly wired from salt fog study
105	U57	TQFP-208	.53k unstable
105	U31	TQFP-208	Failed
105	U48	TQFP-208	Failed
105	U34	TQFP-208	Failed
143	U3	TQFP-208	22 unstable
143	U57	TQFP-208	Failed
143	U31	TQFP-208	Failed/unstable
143	U48	TQFP-208	Failed/unstable
143	U34	TQFP-208	.17k unstable
145	U57	TQFP-208	Failed/unstable
145	U48	TQFP-208	Failed/unstable
145	U34	TQFP-208	Failed

Modal Analysis

CirVibe software was used to create a model to represent the structural dynamic behavior of the PCB boards with stiffeners. CirVibe is a finite element analysis based software that is used for predicting and modeling how vibration will affect a circuit card. The software uses fatigue curves, in particular the slope of the S-N plot (stress vs. cycles to failure), to calculate the damage accumulation rate for each component on the circuit card. The modal analysis included natural frequencies and damage values for specified parts located on the board. A variety of simulations with different stiffener arrangements were run using the CirVibe software and, it was determined that a single stiffener running lengthwise down the center of the board was sufficient to significantly reduce the stresses and damage to the components on the boards. Thus, this approach was decided upon for stiffening the boards. The stiffeners were machined using 60-61 Aluminum, their measurements were 12 ¼” long by ¼” thick and 3/8” in high. The application of the stiffeners to the PCB board was done using instant adhesive designed for circuit board assembly with tensile shear strength of 3,200 psi.

Three accelerometers were placed on each PCB board in locations determined by the CirVibe software in order to record the regions of largest deflection. Coordinates at Peak Displacement were found to be, #1 in the x direction and y direction-(6.320in., 0), #2 (6.32in., 9.0in.) and #3 (3.640in., 0).

The accelerometers were then glued onto each PCB board using the same instant adhesive. Accelerometers were given designations of top right (TR) top left (TL) and bottom center (BC) for recording purposes. All accelerometers were placed in the direction of the z-axis for recording data in the direction of maximum deflection. The modal analysis included natural frequencies and damage values for specified parts located on the board.

Event Detector

Each of the fifty-five components was individually monitored using the two Event Detectors. Sixteen plugs and 512 channels were utilized in this process with the channels for board #36 being dispersed through out. Settings on the event detector software were set to record data at 60 minutes per run with 5 minute cycles, recording 10 times per 5 minute cycle. The event detectors continuously scanned for events, and were polled by the computer every 30 seconds. The event detector was set to a 300 ohm threshold. A base line was taken while PCB boards were in the test fixture. This was done to compare the data to the original continuity test and see which components had failures (events) before vibration testing began. An image of the event detector can be seen in Figure 1.

Figure 1. The event detectors with the wire bundles plugged into them. The two detectors combined allowed for 512 channels to be monitored simultaneously.

Vibration Testing

Vibration testing occurred at the White Sands Missle Range (WSMR) using a long stroke shaker with 2 inch displacement. A resonance sweep was done on the test fixture box to determine its resonant frequency. The nine PCB boards were subjected to the same vibration levels as the original study as shown. Testing conditions consisted of one hour of vibration at 9.9 Grms in y-axis, followed by the same in the x-axis and z-axis. Vibration was then conducted in the z-axis starting at 12 Grms for one hour. The vibration levels increased in 2 Grms increments shaking for one hour each until reaching 20 Grms. One additional level at 28 Grms was then conducted. Figures 2, 3 and 4 show the various x, y, and z-axes of the test fixture.

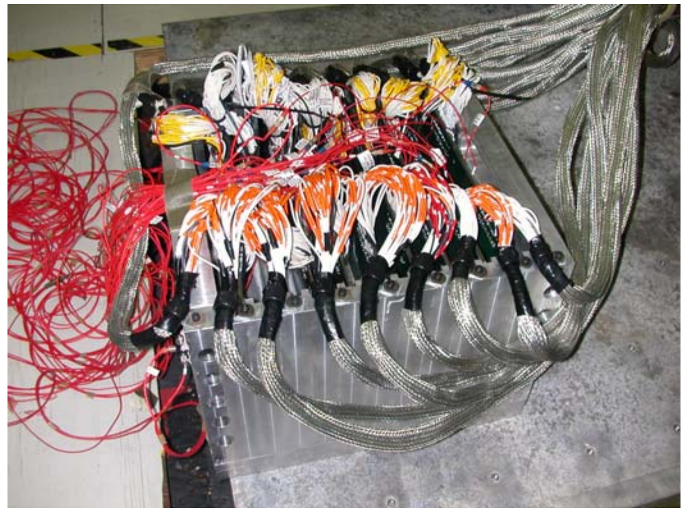

Figure 2. Y-axis setup

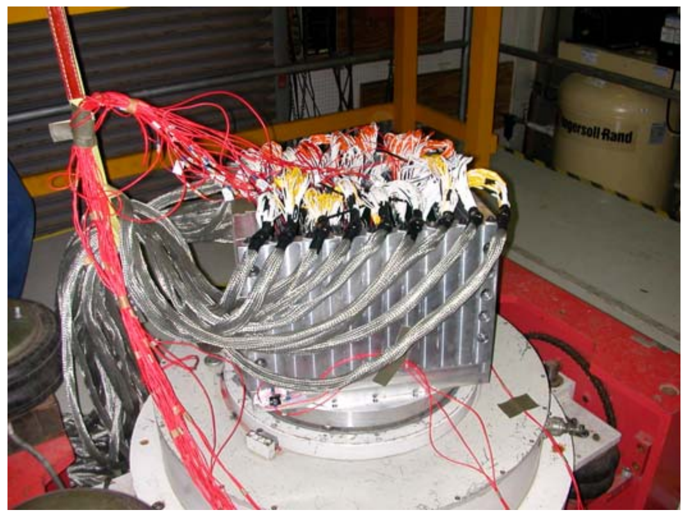

Figure 3. X-axis setup

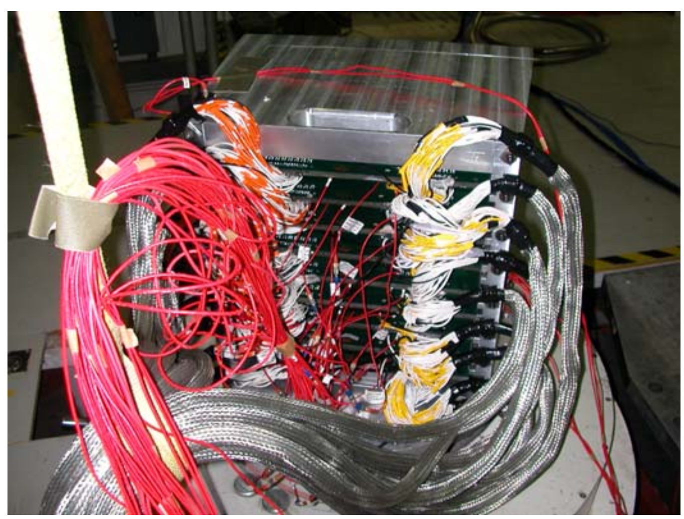

Figure 4. Z-axis setup

RESULTS AND DISCUSSION

The completion of this test provided an alternate set of data to compare with the original JCAA/JGPP vibration study. The primary variables in this study compared to the original were the presence of stiffeners on the boards, and the additional accelerometers. The extra accelerometers allowed for a more detailed characterization of the vibration modes than the original study.

The stiffeners were attached using instant adhesive, as it was impossible to use screws to attach the stiffeners without causing shorts to the electrical leads. The adhesive used was a very strong adhesive, but unfortunately it was not strong enough to keep the stiffeners attached to the boards. Most of the stiffeners became detached during the first level of vibration in the z-axis, though one stiffener did not detach until the second level of vibration. Despite the fact that the stiffeners did not stay on for the duration of the test, the results from this study did show marked improvement from the original study. Table 2 shows the overall improvement between tests.

Table 2. Comparison of overall failure percentages showing an improvement from the JCAA/JGPP study.

Axis	Test Level	% Failed (JCAA/JGPP)	%Failed (METTOP)	Amount of Stiffeners at end of level
Y-axis	9.9 Grms	0	0	9
X-axis	9.9 Grms	0	0	8
Z-axis	9.9 Grms	7.7	5.5	4
Z-axis	12.0 Grms	17.7	9.9	0
Z-axis	14.0 Grms	29.2	17.2	0
Z-axis	16.0 Grms	39.1	26.1	0
Z-axis	18.0 Grms	46.9	33.0	0
Z-axis	20.0 Grms	55.6	43.1	0
Z-axis	28.0 Grms	68.4	54.2	0

As can be seen in the above table there was an increase of component failures due to the increase in Grms, but the overall percentages were less than the original study. As in the original study, no failures occurred in the X and Y directions. After the stiffeners fell off, the damage percent increased at close to the same rate as the original study, indicating that the stiffeners did help in mitigating damage on the first levels of vibration.

In the paper "Methodology for Evaluating Data for "Reverse Compatibility" of Solder Joints" [3], Bill Russell, Dennis Fritz and Gary Latta do a very comprehensive analysis of the original JCAA/JGPP vibration data. Through this analysis they were able to assign different "strain regions" to the boards, or areas that receive roughly equal amounts of strain. Each region has approximately an equal numbers of components in it. Figure 5 shows a diagram of the board with different strain regions color coded. The areas of highest strain were determined to be the blue region (edge) and the red region (center), and the yellow region is the area of least strain. This analysis agrees with what the CirVibe software predicts. The edge regions receive

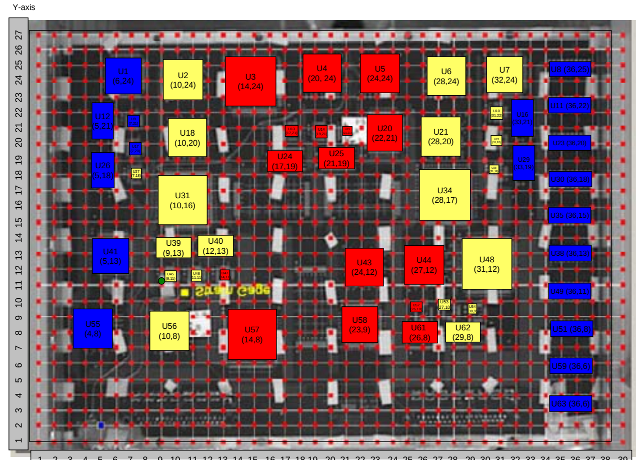

Figure 5. One of the PCB boards showing the different stress regions. Red and blue indicate the high stress areas, and yellow indicates the lower stress area.

increased stress due to the presence of the bending around the wedge clamps. The center of the board deflects significantly producing stress in this region. Assigning these stress regions makes it easier to compare components, keeping the comparison within a stress region, rather than comparing components in different stress regions. Adding stiffeners to the boards reduces the deflections, thus resulting in lower overall stress. One would still expect the highest stress regions to be around the edges and in the center, but it should be less than without the stiffener. By looking at the failures in each stress region of the original study, and the new study a visual comparison can be made. Figure 6 shows how the two studies compare when examining the part failures in each stress region. In both studies, the components in the low stress region performed very well with few failures. The exception to this

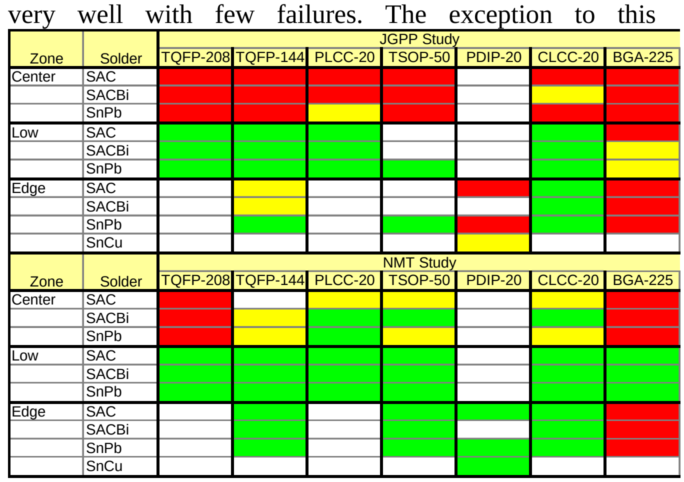

Figure 6. A visual comparison of the overall failures in the different regions for the two tests. Red means it failed in the first three levels, yellow means it failed in the second two levels, and green means it failed either in the last two levels or it never failed.

in the original study was the BGA-225s, which failed early on even in the low stress region. The results from the latest study show that all of the parts in the low stress regions lasted to the highest levels of vibration, even the BGAs.

The areas that show the most marked improvement are the center and edge areas, where significantly fewer failures were seen. What follows is a summary of each component type and a description of what was observed, as compared to the original study.

Individual Component Observations

BGA-225's

The BGAs in the center and edge regions failed very quickly, mostly within the first three levels of vibration. This was not surprising, and agreed with the original study for the most part. In the edge region, the SnPb BGA's performed better than the original study, and outperformed both SAC and SACBi. In the lower stress region, the SnPb BGA's outperformed the lead-free alloys significantly, with almost all of the BGA's surviving to the highest levels of vibration.

TQFP-208's

The TQFP-208 sample size was fairly small due to the significant number that had failed from salt fog corrosion. Observations of the remaining TQFP-208's did not show any significant variations from the original study. Those in the center region failed almost immediately, while those in the lower stress region fared better. About 2/3 of them lasted until the highest levels. No variation in solder alloy performance was observed.

TQFP-144's

The TQFP-144's tended to perform significantly better than in the original test. In the center region, SnPb solder outperformed the lead-free alloys. For the edge region, SAC and SACBi slightly outperformed SnPb.

PLCC-20's

All of the PLCC-20's in the low stress region lasted to the highest levels, which was unchanged from the original study. In the center region, all of those soldered with SACBi performed the best, with all of them lasting to the end. SnPb also did well, with 83% of them lasting to the end. This was an improvement from the original study.

TSOP-50's

The TSOP-50's that showed the most significant improvement were those in the center stress zone. In the original study the majority of these components failed in the first three levels of vibration. The new study showed failures that were more distributed throughout the levels. The parts soldered with SACBi performed the best, with 56% of them lasting to the highest levels of vibration as compared to 0% in the original study.

PDIP-20's

All of the PDIP-20's were located in the edge stress region of the boards. In the original study, the parts with SnCu alloy performed the best; with 58% of them failing in the highest three levels. Also, in the original study SAC and SnPb alloys performed much worse, with 58% and 55% failing in the first three levels of vibration. These numbers improved significantly with the latest study, with the majority of all three alloys surviving to the highest levels. The percentages of those lasting to the end were 69% for SAC, 90% for SnCu and 73% for SnPb.

CLCC-20's

The CLCC-20's were spread out through all three stress regions, and in both studies most of them lasted to the end in both the low stress region and the edge regions. The components in the center region however did show some improvement with more of the parts not failing until higher levels. The percentages of those failing in the highest levels of the original study were 0% for SAC, 33% for SACBi, and 33% for SnPb as compared to 33% for SAC, 56% for SACBi and 33% for SnPb in the latest study.

Overall, it appears that SACBi and SnPb showed the highest reliability and best performance. The low stress region showed very few failures, thus all three alloys appeared to perform equally well in this region. SAC tended to perform the most poorly, and in very few cases did SAC outperform either of the other two alloys.

Accelerometer Data

This test produced a wealth of accelerometer data on the boards, due to the presence of three accelerometers per board, one accelerometer at the point of maximum displacement for mode 1, one for the point of maximum displacement of mode 2, and one for the point of maximum displacement for mode 3. The intent of the accelerometer placement was to be able to characterize the first three modes of vibration in greater detail than the original test. In vibration testing the first three modes are of most interest since most of damage occurs within these modes. Every accelerometer was placed carefully in order to better characterize each mode. The end result indicated three distinct resonances. Interestingly, all three accelerometers appeared to characterize modes 1 and 7 quite well, with little disagreement between values, all around 70 Hz for mode 1 and 440 Hz for mode 7. Modes 2 and 3 were more difficult to identify. The data was not as clear, yet we were still able to characterize modes 2 and 3 for most of the boards. Mode 2 was approximately 135 Hz and mode 3 was approximately 212 Hz. Mode one matches up with the first distinct resonant peak and modes 2 and 3 are somewhere between the first resonant peak and the 7^{th}. Figure 7 is an example of accelerometer vibration run with resonance peaks at 70 Hz, 440 Hz, and 1080 Hz respectively.

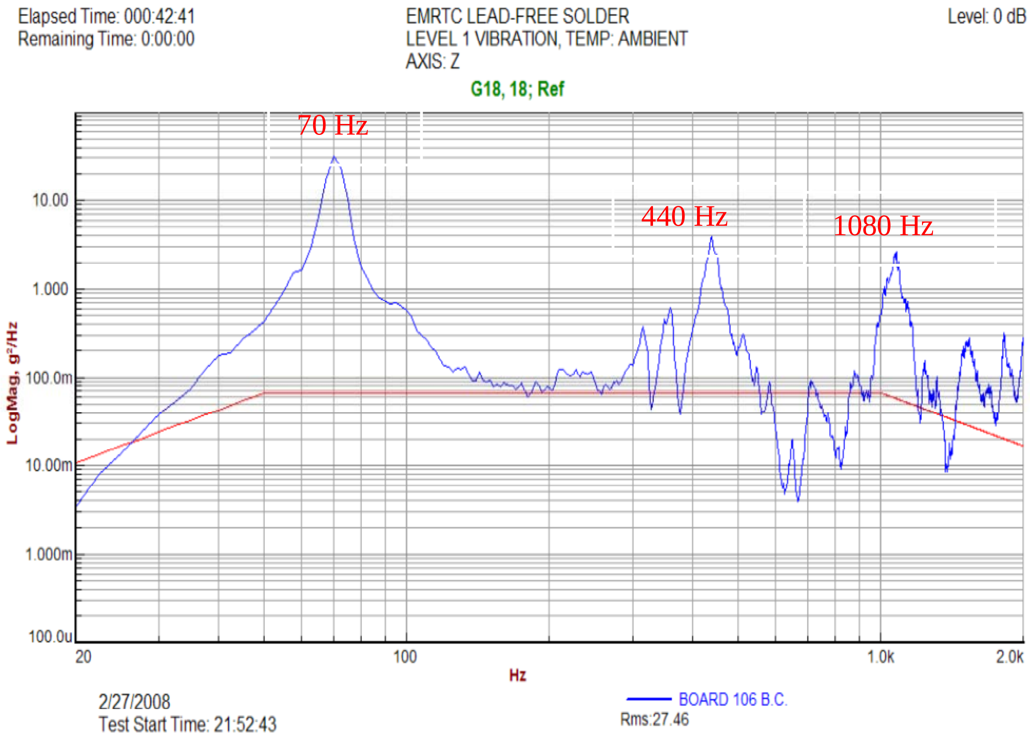

Figure 7. An accelerometer graph, showing three of the resonant frequencies of the circuit board during the first level of vibration in the z-axis.

CONCLUSIONS

The results of this study showed a definite reduction in the failure rate from the original study, but it is not certain whether this improvement can be attributed to the stiffeners or not. More studies such as this will be needed before definite conclusions can be drawn. Analysis of the data from this study is ongoing. Future work will focus on better characterizing the modes of vibration, and using this information to do a more rigorous analysis of which components received the most damage.

ACKNOWLEDGEMENTS

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Thanks to everyone on the Project 1722 team for your input and support throughout the process of conducting this test, and for providing the PCB boards for testing.

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Appendix A: Time to Failure Charts

U12: TSOP-50										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	60	2	
105	SAC/SAC	60	60	60	60	60	60	60	60	7
106	SAC/SAC	60	60	60	60	60	60	5		
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	1
35	SnPb/SnPb	60	60	60	2					
36	SnPb/SnPb	60	60	60	60	60	2			
37	SnPb/SnPb	60	60	60	60	60	60	60	2	

U16: TSOP-50										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	60	60	60
105	SAC/SAC	60	60	60	60	60	60	60	60	60
106	SAC/SAC	60	60	60	60	60	60	60	60	60
143	SACB/SAC	60	60	60	60	60	60	60	32	
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U24: TSOP-50										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	12				
105	SAC/SAC	60	60	60	60	60	60	12		
106	SAC/SAC	60	60	60	60	60	60	2		
143	SACB/SAC	60	60	60	60	60	52			
144	SACB/SAC	60	60	60	60	60	60	12		
145	SACB/SAC	60	60	60	60	60	60	60	60	16
35	SnPb/SnPb	60	60	60	60	60	2			
36	SnPb/SnPb	60	60	60	60	60	60	31		
37	SnPb/SnPb	60	60	60	60	60	16			

U25: TSOP-50

Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	11			
105	SAC/SAC	60	60	60	60	60	30			
106	SAC/SAC	60	60	60	60	60	2			
143	SACB/SAC	60	60	60	60	60	60	60	2	
144	SACB/SAC	60	60	60	60	60	60	27		
145	SACB/SAC	60	60	60	60	60	47			
35	SnPb/SnPb	60	60	60	60	12				
36	SnPb/SnPb	60	60	60	60	60	30			
37	SnPb/SnPb	60	60	60	60	27				

U26: TSOP-50										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	60	0	
105	SAC/SAC	60	60	60	60	60	60	60	60	20
106	SAC/SAC	60	60	60	60	60	60	22		
143	SACB/SAC	60	60	60	60	60	60	60	60	11
144	SACB/SAC	60	60	60	60	60	60	60	56	
145	SACB/SAC	60	60	60	60	60	60	60	60	2
35	SnPb/SnPb	60	60	60	60	46				
36	SnPb/SnPb	60	60	60	60	60	60	60	56	
37	SnPb/SnPb	60	60	60	60	60	60	60	60	16

U29: TSOP-50										
Board Number	**Solder/Finish**	**Time at Each Level (minutes)**								
		Y-axis	**X-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**
		9.9 Grms	**9.9 Grms**	**9.9 Grms**	**12.0 Grms**	**14.0 Grms**	**16.0 Grms**	**18.0 Grms**	**20.0 Grms**	**28.0 Grms**
104	SAC/SAC	60	60	60	60	60	60	60	60	60
105	SAC/SAC	60	60	60	60	60	60	60	60	60
106	SAC/SAC	60	60	60	60	60	60	60	60	60
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U39: TSOP-50										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	60	60	60
105	SAC/SAC	60	60	60	60	60	60	60	60	60
106	SAC/SAC	60	60	60	60	60	60	60	60	60
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U40: TSOP-50										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	60	60	17
105	SAC/SAC	60	60	60	60	60	60	60	60	60
106	SAC/SAC	60	60	60	60	60	60	60	60	60
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	60	52
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U61: TSOP-50										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	60	60	7
105	SAC/SAC	60	60	60	60	60	60	60	51	
106	SAC/SAC	60	60	60	60	60	60	60	51	
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	2
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	17	
36	SnPb/SnPb	60	60	60	60	60	60	60	32	
37	SnPb/SnPb	60	60	60	60	60	60	60	11	

U62: TSOP-50										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	60	60	60
105	SAC/SAC	60	60	60	60	60	60	60	60	60
106	SAC/SAC	60	60	60	60	60	60	60	60	37
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	52
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	32

U1: TQFP-144										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	60	34	
105	SAC/SAC	60	60	60	60	60	60	60	7	
106	SAC/SAC	60	60	60	60	60	60	60	32	
143	SACB/SAC	60	60	60	60	60	60	60	60	17
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	20
35	SnPb/SnPb	60	60	60	60	60	31			
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	31	

U7: TQFP-144										
Board Number	**Solder/Finish**	**Time at Each Level (minutes)**								
		Y-axis	**X-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**
		9.9 Grms	**9.9 Grms**	**9.9 Grms**	**12.0 Grms**	**14.0 Grms**	**16.0 Grms**	**18.0 Grms**	**20.0 Grms**	**28.0 Grms**
104	SAC/SAC	60	60	60	60	60	60	60	60	60
105	SAC/SAC	60	60	60	60	60	60	60	60	60
106	SAC/SAC	60	60	60	60	60	60	60	60	60
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U20: TQFP-144										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	31			
105	SAC/SAC	60	60	60	60	60	12			
106	SAC/SAC	60	60	60	60	60	22			
143	SACB/SAC	60	60	60	60	60	60	35		
144	SACB/SAC	60	60	60	60	60	1			
145	SACB/SAC	60	60	60	60	60	17			
35	SnPb/SnPb	60	60	60	60	60	60	2		
36	SnPb/SnPb	60	60	60	60	60	60	7		
37	SnPb/SnPb	60	60	60	60	50				

U41: TQFP-144										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	60	5	
105	SAC/SAC	60	60	60	60	60	42			
106	SAC/SAC	60	60	60	60	60	60	60	17	
143	SACB/SAC	60	60	60	60	60	60	60	60	2
144	SACB/SAC	60	60	60	60	60	11			
145	SACB/SAC	60	60	60	60	60	60	60	60	37
35	SnPb/SnPb	60	60	60	60	60	55			
36	SnPb/SnPb	60	60	60	60	60	60	7		
37	SnPb/SnPb	60	60	60	60	60	60	60	60	51

U58: TQFP-144										
Board Number	**Solder/Finish**	**Time at Each Level (minutes)**								
		Y-axis	**X-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**
		9.9 Grms	**9.9 Grms**	**9.9 Grms**	**12.0 Grms**	**14.0 Grms**	**16.0 Grms**	**18.0 Grms**	**20.0 Grms**	**28.0 Grms**
104	SAC/SAC	60	60	60	60	27				
105	SAC/SAC	60	60	60	60	47				
106	SAC/SAC	60	60	60	60	12				
143	SACB/SAC	60	60	60	60	22				
144	SACB/SAC	60	60	60	42					
145	SACB/SAC	60	60	60	60	60	17			
35	SnPb/SnPb	60	60	60	60	60	27			
36	SnPb/SnPb	60	60	60	60	60	22			
37	SnPb/SnPb	60	60	60	60	60	17			

U3: TQFP-208										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	bad part								
105	SAC/SAC	bad part								
106	SAC/SAC	60	60	2						
143	SACB/SAC	bad part								
144	SACB/SAC	60	60	60	42					
145	SACB/SAC	60	60	7						
35	SnPb/SnPb	60	60	60	2					
36	SnPb/SnPb	60	60	2						
37	SnPb/SnPb	60	60	60	2					

U31: TQFP-208										
Board Number	**Solder/Finish**	**Time at Each Level (minutes)**								
		Y-axis 9.9 Grms	**X-axis 9.9 Grms**	**Z-axis 9.9 Grms**	**Z-axis 12.0 Grms**	**Z-axis 14.0 Grms**	**Z-axis 16.0 Grms**	**Z-axis 18.0 Grms**	**Z-axis 20.0 Grms**	**Z-axis 28.0 Grms**
104	SAC/SAC	60	60	60	60	60	60	60	60	60
105	SAC/SAC	bad part								
106	SAC/SAC	60	60	60	60	60	60	60	60	60
143	SACB/SAC	bad part								
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	17
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U34: TQFP-208										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	bad part								
105	SAC/SAC	bad part								
106	SAC/SAC	60	60	60	60	60	60	17		
143	SACB/SAC	bad part								
144	SACB/SAC	60	60	60	60	60	60	10		
145	SACB/SAC	bad part								
35	SnPb/SnPb	60	60	60	60	60	60	60	60	22
36	SnPb/SnPb	60	60	60	60	60	60	60	31	
37	SnPb/SnPb	60	60	60	60	60	51			

U48: TQFP-208										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	bad part								
105	SAC/SAC	bad part								
106	SAC/SAC	60	60	60	60	60	60	60	60	5
143	SACB/SAC	bad part								
144	SACB/SAC	60	60	60	60	60	60	60	52	
145	SACB/SAC	bad part								
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	5

U57: TQFP-208										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	bad part								
105	SAC/SAC	bad part								
106	SAC/SAC	60	60	60	42					
143	SACB/SAC	bad part								
144	SACB/SAC	60	60	60	37					
145	SACB/SAC	bad part								
35	SnPb/SnPb	60	60	60	60	12				
36	SnPb/SnPb	60	60	60	60	7				
37	SnPb/SnPb	60	60	60	60	27				

U2: BGA-225										
Board Number	**Solder/Finish**	**Time at Each Level (minutes)**								
		Y-axis	**X-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**
		9.9 Grms	**9.9 Grms**	**9.9 Grms**	**12.0 Grms**	**14.0 Grms**	**16.0 Grms**	**18.0 Grms**	**20.0 Grms**	**28.0 Grms**
104	SAC/SAC	60	60	60	60	11				
105	SAC/SAC	60	60	60	60	60	60	60	60	60
106	SAC/SAC	60	60	60	60	60	60	60	60	6
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U4: BGA-225										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	2						
105	SAC/SAC	60	60	27						
106	SAC/SAC	60	60	22						
143	SACB/SAC	60	60	60	42					
144	SACB/SAC	60	60	2						
145	SACB/SAC	60	60	20						
35	SnPb/SnPb	60	60	60	2					
36	SnPb/SnPb	60	60	60	2					
37	SnPb/SnPb	60	60	60	2					

U5: BGA-225										
Board Number	**Solder/Finish**	**Time at Each Level (minutes)**								
		Y-axis	**X-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**
		9.9 Grms	**9.9 Grms**	**9.9 Grms**	**12.0 Grms**	**14.0 Grms**	**16.0 Grms**	**18.0 Grms**	**20.0 Grms**	**28.0 Grms**
104	SAC/SAC	60	60	60	2					
105	SAC/SAC	60	60	60	60	32				
106	SAC/SAC	60	60	2						
143	SACB/SAC	60	60	60	37					
144	SACB/SAC	60	60	60	28					
145	SACB/SAC	60	60	2						
35	SnPb/SnPb	60	60	60	60	7				
36	SnPb/SnPb	60	60	2						
37	SnPb/SnPb	60	60	60	2					

U6: BGA-225										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	22				
105	SAC/SAC	60	60	60	2					
106	SAC/SAC	60	60	2						
143	SACB/SAC	60	60	60	60	60	60	12		
144	SACB/SAC	60	60	60	60	45				
145	SACB/SAC	60	60	60	60	0				
35	SnPb/SnPb	60	60	60	60	60	60	60	60	20
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	11	

U18: BGA-225										
Board Number	**Solder/Finish**	**Time at Each Level (minutes)**								
		Y-axis	**X-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**
		9.9 Grms	**9.9 Grms**	**9.9 Grms**	**12.0 Grms**	**14.0 Grms**	**16.0 Grms**	**18.0 Grms**	**20.0 Grms**	**28.0 Grms**
104	SAC/SAC	60	60	60	60	60	60	60	60	7
105	SAC/SAC	60	60	60	60	60	60	60	60	25
106	SAC/SAC	60	60	60	60	60	60	60	60	2
143	SACB/SAC	60	60	60	60	60	60	60	60	47
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	x						
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U21: BGA-225										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	57		
105	SAC/SAC	60	60	0						
106	SAC/SAC	60	60	60	60	60	36			
143	SACB/SAC	60	60	60	60	2				
144	SACB/SAC	60	60	60	60	60	60	60	22	
145	SACB/SAC	60	60	60	60	60	60	22		
35	SnPb/SnPb	60	60	60	60	60	60	60	60	7
36	SnPb/SnPb	60	60	60	60	60	60	60	60	20
37	SnPb/SnPb	60	60	60	60	60	60	32		

U43: BGA-225										
Board Number	**Solder/Finish**	**Time at Each Level (minutes)**								
		Y-axis	**X-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**
		9.9 Grms	**9.9 Grms**	**9.9 Grms**	**12.0 Grms**	**14.0 Grms**	**16.0 Grms**	**18.0 Grms**	**20.0 Grms**	**28.0 Grms**
104	SAC/SAC	60	60	2						
105	SAC/SAC	60	60	27						
106	SAC/SAC	60	60	2						
143	SACB/SAC	60	60	60	32					
144	SACB/SAC	60	60	2						
145	SACB/SAC	60	60	2						
35	SnPb/SnPb	60	60	2						
36	SnPb/SnPb	60	60	60	60	27				
37	SnPb/SnPb	60	60	60	60	21				

U44: BGA-225										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	17				
105	SAC/SAC	60	60	60	60	12				
106	SAC/SAC	60	60	60	60	60	60	60	60	60
143	SACB/SAC	60	60	60	60	60	50			
144	SACB/SAC	60	60	60	60	12				
145	SACB/SAC	60	60	60	60	16				
35	SnPb/SnPb	60	60	60	60	60	60	60	27	
36	SnPb/SnPb	60	60	60	60	40				
37	SnPb/SnPb	60	60	60	60	60	42			

U55: BGA-225										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	2						
105	SAC/SAC	60	60	27						
106	SAC/SAC	60	60	60	2					
143	SACB/SAC	60	60	2						
144	SACB/SAC	60	60	2						
145	SACB/SAC	60	60	27						
35	SnPb/SnPb	60	60	60	60	15				
36	SnPb/SnPb	60	60	2						
37	SnPb/SnPb	60	60	60	60	60	12			

U56: BGA-225										
Board Number	**Solder/Finish**	**Time at Each Level (minutes)**								
		Y-axis	**X-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**
		9.9 Grms	**9.9 Grms**	**9.9 Grms**	**12.0 Grms**	**14.0 Grms**	**16.0 Grms**	**18.0 Grms**	**20.0 Grms**	**28.0 Grms**
104	SAC/SAC	bad part								
105	SAC/SAC	60	60	60	60	60	60	60	60	27
106	SAC/SAC	60	60	2						
143	SACB/SAC	60	60	60	60	60	60	60	60	2
144	SACB/SAC	60	60	60	60	60	2			
145	SACB/SAC	60	60	60	60	60	60	60	60	25
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U15: PLCC-20										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	12		
105	SAC/SAC	60	60	60	60	60	60	42		
106	SAC/SAC	60	60	60	60	60	60	39.5		
143	SACB/SAC	60	60	60	60	60	60	60	2	
144	SACB/SAC	60	60	60	60	60	60	60	60	35
145	SACB/SAC	60	60	60	60	60	60	60	25	
35	SnPb/SnPb	60	60	60	60	60	60	60	60	2
36	SnPb/SnPb	60	60	60	60	60	60	7		
37	SnPb/SnPb	60	60	60	60	60	60	60	60	27

U27: PLCC-20										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	60	60	60
105	SAC/SAC	60	60	60	60	60	60	60	60	60
106	SAC/SAC	60	60	60	60	60	60	60	60	60
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U28: PLCC-20										
Board Number	**Solder/Finish**	**Time at Each Level (minutes)**								
		Y-axis	**X-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**
		9.9 Grms	**9.9 Grms**	**9.9 Grms**	**12.0 Grms**	**14.0 Grms**	**16.0 Grms**	**18.0 Grms**	**20.0 Grms**	**28.0 Grms**
104	SAC/SAC	60	60	60	60	60	60	60	60	60
105	SAC/SAC	60	60	60	60	60	60	60	60	60
106	SAC/SAC	60	60	60	60	60	60	60	60	60
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U47: PLCC-20										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	60	60	60
105	SAC/SAC	60	60	60	60	60	60	60	60	60
106	SAC/SAC	60	60	60	60	60	60	60	60	60
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U54: PLCC-20										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	60	60	60
105	SAC/SAC	60	60	60	60	60	60	60	60	60
106	SAC/SAC	60	60	60	60	60	60	60	60	60
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U8: PDIP-20

Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	17		
105	SAC/SAC	60	60	60	60	60	60	27		
106	SAC/SAC	60	60	60	60	60	60	60	60	37
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	12	
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	0	
36	SnPb/SnPb	60	60	60	60	60	60	60	17	
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U11: PDIP-20										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	60	46	
105	SAC/SAC	60	60	60	60	60	60	60	2	
106	SAC/SAC	60	60	60	60	60	60	60	60	32
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	32		
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	16			
36	SnPb/SnPb	60	60	60	60	60	60	60	6	
37	SnPb/SnPb	60	60	60	60	60	60	60	41	

U23: PDIP-20										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	60	60	60
105	SAC/SAC	60	60	60	60	60	60	60	60	60
106	SAC/SAC	60	60	60	60	60	60	60	60	60
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U30: PDIP-20										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	17		
105	SAC/SAC	60	60	60	60	60	60	60	60	37
106	SAC/SAC	60	60	60	60	60	60	60	60	60
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	7		
36	SnPb/SnPb	60	60	60	60	60	60	60	60	12
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U35: PDIP-20										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	bad part								
105	SAC/SAC	60	60	60	60	60	60	60	60	60
106	SAC/SAC	60	60	60	60	60	60	60	60	7
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	17			
35	SnPb/SnPb	60	60	60	60	60	60	60	42	
36	SnPb/SnPb	60	60	60	60	6				
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U38: PDIP-20										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	51		
105	SAC/SAC	60	60	60	60	60	60	60	60	32
106	SAC/SAC	60	60	60	60	60	60	60	60	60
143	SACB/SAC	60	60	60	60	60	60	60	60	52
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	45		
36	SnPb/SnPb	60	60	60	60	60	60	60	60	27
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U49: PDIP-20										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	2					
105	SAC/SAC	60	60	60	60	60	60	60	60	42
106	SAC/SAC	60	60	60	60	60	60	60	60	60
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	52			
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U51: PDIP-20

Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	31				
105	SAC/SAC	60	60	60	60	60	60	60	60	42
106	SAC/SAC	60	60	60	60	60	60	60	60	60
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	17	
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U59: PDIP-20										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	60	60	60
105	SAC/SAC	60	60	60	60	60	60	60	60	60
106	SAC/SAC	60	60	60	60	60	60	60	60	60
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U63: PDIP-20										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	12				
105	SAC/SAC	60	60	60	60	60	37			
106	SAC/SAC	60	60	60	60	60	60	42		
143	SACB/SAC	60	60	60	60	60	60	60	12	
144	SACB/SAC	60	60	60	47					
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	1			
36	SnPb/SnPb	60	60	60	60	60	17			
37	SnPb/SnPb	60	60	60	60	56				

U9: CLCC-20										
Board Number	**Solder/Finish**	**Time at Each Level (minutes)**								
		Y-axis	**X-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**
		9.9 Grms	**9.9 Grms**	**9.9 Grms**	**12.0 Grms**	**14.0 Grms**	**16.0 Grms**	**18.0 Grms**	**20.0 Grms**	**28.0 Grms**
104	SAC/SAC	60	60	60	60	60	60	60	60	60
105	SAC/SAC	60	60	60	60	60	60	60	60	60
106	SAC/SAC	60	60	60	60	60	60	60	60	60
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U10: CLCC-20										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	60	60	60
105	SAC/SAC	60	60	60	60	60	60	60	60	60
106	SAC/SAC	60	60	60	60	60	52			
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U13: CLCC-20

Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	57				
105	SAC/SAC	60	60	60	60	60	60	60	25	
106	SAC/SAC	60	60	60	60	60	31			
143	SACB/SAC	60	60	60	60	60	60	27		
144	SACB/SAC	60	60	60	60	60	60	60	22	
145	SACB/SAC	60	60	60	60	60	60	60	12	
35	SnPb/SnPb	60	60	60	60	60	47			
36	SnPb/SnPb	60	60	60	60	60	32			
37	SnPb/SnPb	60	60	60	60	60	60	30		

U14: CLCC-20										
Board Number	**Solder/Finish**	**Time at Each Level (minutes)**								
		Y-axis	**X-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**
		9.9 Grms	**9.9 Grms**	**9.9 Grms**	**12.0 Grms**	**14.0 Grms**	**16.0 Grms**	**18.0 Grms**	**20.0 Grms**	**28.0 Grms**
104	SAC/SAC	60	60	60	60	60	60	60	60	60
105	SAC/SAC	60	60	60	60	60	27			
106	SAC/SAC	60	60	60	60	7				
143	SACB/SAC	60	60	60	60	60	60	22		
144	SACB/SAC	60	60	60	60	60	32			
145	SACB/SAC	60	60	60	60	60	52			
35	SnPb/SnPb	60	60	60	60	60	31			
36	SnPb/SnPb	60	60	60	60	26				
37	SnPb/SnPb	60	60	60	60	32				

U17: CLCC-20										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	60	60	60
105	SAC/SAC	60	60	60	60	60	60	60	60	60
106	SAC/SAC	60	60	60	60	60	60	60	60	60
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U22: CLCC-20										
Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	60	60	60
105	SAC/SAC	60	60	60	60	60	60	60	60	60
106	SAC/SAC	60	60	60	60	60	60	60	60	60
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U45: CLCC-20

Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	60	60	60
105	SAC/SAC	60	60	60	60	60	60	60	60	60
106	SAC/SAC	60	60	60	60	60	60	60	60	60
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

U46: CLCC-20										
Board Number	**Solder/Finish**	**Time at Each Level (minutes)**								
		Y-axis	**X-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**	**Z-axis**
		9.9 Grms	**9.9 Grms**	**9.9 Grms**	**12.0 Grms**	**14.0 Grms**	**16.0 Grms**	**18.0 Grms**	**20.0 Grms**	**28.0 Grms**
104	SAC/SAC	60	60	60	60	60	60	60	60	60
105	SAC/SAC	60	60	60	60	60	60	60	60	60
106	SAC/SAC	60	60	60	60	60	60	60	60	60
143	SACB/SAC	60	60	60	60	60	60	60	60	60
144	SACB/SAC	60	60	60	60	60	60	60	60	60
145	SACB/SAC	60	60	60	60	60	60	60	60	60
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	60
37	SnPb/SnPb	60	60	60	60	60	60	60	60	60

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Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	7		
105	SAC/SAC	60	60	60	60	60	60	60	37	
106	SAC/SAC	60	60	60	60	60	60	12		
143	SACB/SAC	60	60	60	60	60	60	60	60	47
144	SACB/SAC	60	60	60	60	60	60	60	17	
145	SACB/SAC	60	60	60	60	60	60	60	32	
35	SnPb/SnPb	60	60	60	60	60	60	60	10	
36	SnPb/SnPb	60	60	60	60	60	60	60	21	
37	SnPb/SnPb	60	60	60	60	60	60	60	27	

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Board Number	Solder/Finish	Time at Each Level (minutes)								
		Y-axis	X-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis	Z-axis
		9.9 Grms	9.9 Grms	9.9 Grms	12.0 Grms	14.0 Grms	16.0 Grms	18.0 Grms	20.0 Grms	28.0 Grms
104	SAC/SAC	60	60	60	60	60	60	60	60	36
105	SAC/SAC	60	60	60	60	60	60	60	60	1
106	SAC/SAC	60	60	60	60	60	60	60	60	0
143	SACB/SAC	60	60	60	60	60	60	60	60	52
144	SACB/SAC	60	60	60	60	60	60	16		
145	SACB/SAC	60	60	60	60	60	60	60	42	
35	SnPb/SnPb	60	60	60	60	60	60	60	60	60
36	SnPb/SnPb	60	60	60	60	60	60	60	60	21
37	SnPb/SnPb	60	60	60	60	60	60	60	55	